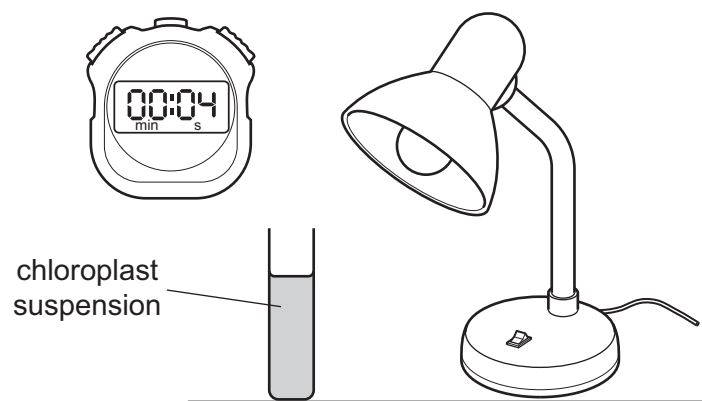


A LEVEL Biology

13. Photosynthesis

Paper 5

2018-2025



Classified by Mr.Adeel Ahmad

MAY/JUNE 2018 Variant 51

- 1 (a) Some students were asked to use leaf discs to investigate photosynthesis in leaves of different types.

The students decided to compare the rate of photosynthesis in four different types of leaf in a room kept at a temperature of 20 °C.

The leaves were taken from:

- ivy, which has a thick waxy cuticle on the upper surface
- geranium, which has a thin cuticle on the upper surface
- spiderwort, which has purple and green stripes and a thin cuticle
- sorghum, which has a thick waxy cuticle on the upper surface.

The students prepared leaf discs of the same diameter from all four types of leaf and placed them onto damp paper in Petri dishes. Each Petri dish was covered by a lid.

When first placed in a solution, the leaf discs sink. As photosynthesis occurs oxygen is released and the discs rise to the surface. The time taken for the discs to reach the surface allows the rate of photosynthesis to be determined.

Fig. 1.1 shows leaf discs rising to the surface after being placed in a solution of sodium hydrogencarbonate.

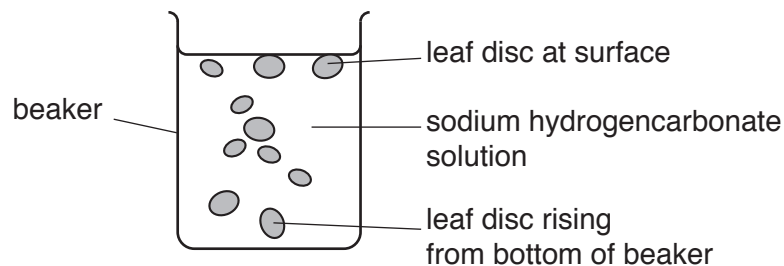


Fig. 1.1

- (i) State the independent variable **and** the dependent variable in this investigation.

independent variable

.....

dependent variable

.....

- (ii) Use the information provided to describe a method by which the students could compare the rate of photosynthesis in discs cut from the four types of leaf.

Your method should be set out in a logical order and be detailed enough to let another person follow it.

Details of the preparation of the leaf discs are **not** required.

..... [7

(b) The students' results are shown in Table 1.1.

Table 1.1

type of leaf	ivy	geranium	spiderwort	sorghum
mean time for leaf discs to reach the surface/s	130	75	95	100

(i) Describe how the students could calculate the rate of photosynthesis from their results.

.....
 [1]

(ii) The students made three conclusions.

conclusion 1

Leaves with a thick cuticle absorb less light and photosynthesise more slowly than leaves with a thin cuticle.

conclusion 2

Leaves of spiderwort have a slower rate of photosynthesis because they have less chlorophyll than other plants.

conclusion 3

Sorghum is a C₄ plant and so its leaves photosynthesise faster than those of ivy which is a C₃ plant.

Each of these conclusions is supported by the evidence, but may **not** be valid.

Explain why each conclusion may **not** be valid, using the information in (a) about the leaves and the method used to determine the rate of photosynthesis.

conclusion 1

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conclusion 2

.....

conclusion 3

.....

[3]

- (c) A colorimeter passes a beam of light through a coloured filter into a solution and measures the light absorbance of that solution.

A standard solution is used to set the colorimeter scale to zero (0) before taking any measurements.

Chlorophyll absorbs red light, so the chlorophyll concentration of a leaf extract can be measured using a colorimeter.

- (i) Outline how the students could use a colorimeter to obtain further evidence to support the conclusion that leaf discs of spiderwort have a lower chlorophyll content than the leaf discs from the other types of leaf investigated.

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..... [3]

- (ii) Suggest a standard solution that could be used in the colorimeter to ensure that light absorbance is due **only** to the chlorophyll in a leaf extract.

..... [1]

- (d) Table 1.2 shows the students' results from the colorimeter measurements made on 10 samples of each of the four types of leaf.

Table 1.2

type of leaf	ivy	geranium	spiderwort	sorghum
mean absorbance $\pm s$	0.28 ± 0.08	0.32 ± 0.1	0.43 ± 0.18	0.39 ± 0.21

The students decided to use the t -test to test the hypothesis that:

The difference in the chlorophyll concentration between spiderwort and each of the other plants is significant.

The formula for the t -test is shown in Fig. 1.2.

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}} \quad \nu = n_1 + n_2 - 2$$

ν = degrees of freedom
 s = standard deviation
 n = sample size (number of observations)
 $\bar{x}$ = mean

Fig. 1.2

Comment on the use of the t -test by:

stating how many values of t the students should calculate **and** explaining your answer

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explaining how the students would find out if the results of their t -tests were significant.

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[4]

[Total: 21]

MAY/JUNE 2018 Variant 52

- 1 During the light dependent stage of photosynthesis, hydrogen ions and electrons are released by the photoactivation of chlorophyll and the photolysis of water. These are added to the carrier molecule, NADP, changing it from an oxidised state to a reduced state, as shown in Fig. 1.1.

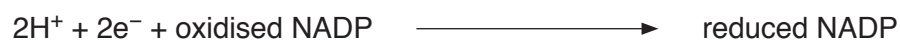


Fig. 1.1

DCPIP is a blue dye which becomes colourless when reduced by hydrogen ions and electrons, as shown in Fig. 1.2.



Fig. 1.2

A student used DCPIP to determine if the reactions in the light dependent stage had occurred in a suspension of chloroplasts.

- The suspension of chloroplasts was prepared by grinding, filtering and centrifuging a sample of leaves with ice-cold extraction medium.
- Four tubes covered in foil were set up containing the mixtures shown in Table 1.1.

Table 1.1

tube	contents
1	chloroplast suspension and DCPIP
2	chloroplast suspension and distilled water
3	DCPIP and extraction medium
4	chloroplast suspension and DCPIP

- The tubes were illuminated through a thin glass tank filled with water as shown in Fig. 1.3.

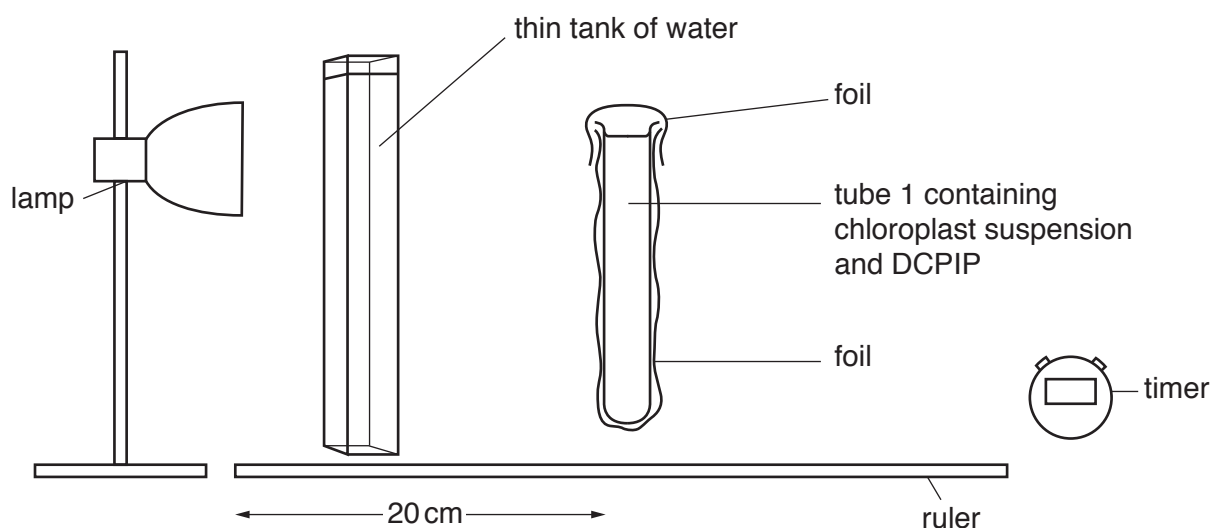


Fig. 1.3

- The foil was removed from tubes 1, 2 and 3, but left on tube 4.
- A timer was started immediately.
- After 10 minutes the colour in each tube was observed and recorded.

Table 1.2 shows the student's results.

Table 1.2

tube	contents	foil	colour after 10 minutes
1	chloroplast suspension and DCPIP	removed	green
2	chloroplast suspension and distilled water	removed	green
3	DCPIP and extraction medium	removed	blue
4	chloroplast suspension and DCPIP	left in place	blue

(a) State why the results in Table 1.2 are qualitative.

.....
 [1]

(b) Explain why tubes 2, 3 and 4 were included.

.....

 [2]

(c) State the function of the thin tank of water.

.....
 [1]

The student then modified the investigation to test the hypothesis:

As light intensity increases the rate of the light dependent stage of photosynthesis will increase.

(d) (i) Identify the independent variable **and** the dependent variable in this investigation.

independent

dependent

[2]

- (ii) Using the apparatus shown in Fig. 1.3, describe a method the student could use to collect the data needed to test their hypothesis.

Your method should be set out in a logical way and be detailed enough to let another person follow it.

..... [7]

- (e) Light intensity (I) can be calculated using the formula shown in Fig. 1.4.

$$I = \frac{1}{\text{distance}^2}$$

Fig. 1.4

Use the formula shown in Fig. 1.4 to calculate the light intensity for the investigation shown in Fig. 1.3.

$I =$ [1]

- (f) The student prepared two tubes with the same contents as tube 1 (Table 1.1) from their original investigation. One tube was exposed to high light intensity and the other tube was exposed to low light intensity.

A colorimeter was used to measure the absorption values of samples taken from these tubes, at one minute intervals, over a period of 12 minutes.

Fig. 1.5 shows the absorption results at high light intensity.

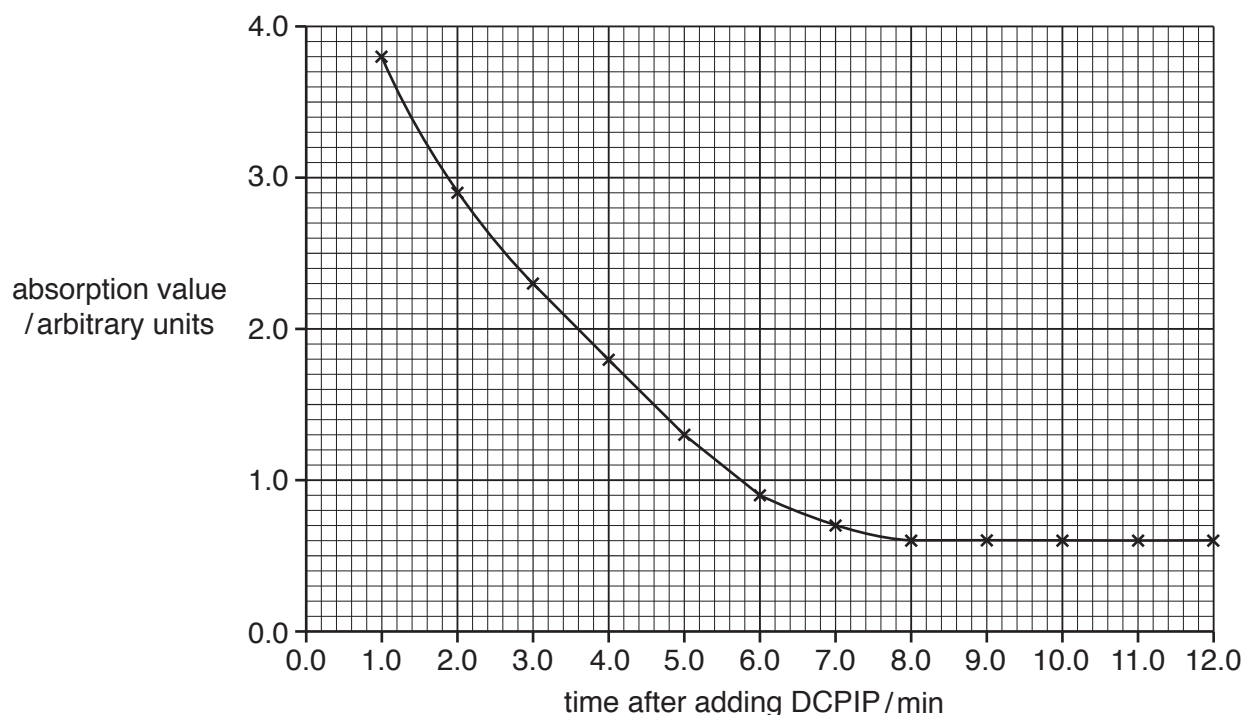


Fig. 1.5

- (i) The student concluded that the reaction reached completion at 8 minutes. State why the data in the graph do **not** support this conclusion.

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 [1]

- (ii) Draw a tangent on Fig. 1.5 **and** use it to calculate the rate of change at 6 minutes.

rate of change at 6 minutes = arbitrary units
 [2]

- (iii) On Fig. 1.5, sketch the curve that you would expect for the tube at low light intensity. [1]

(g) The student then investigated the effect that three different weed killers had on the light dependent reaction.

- Four tubes covered in foil were set up containing the mixtures shown in Table 1.3.
- The volume of each component in the mixtures was standardised.

Table 1.3

tube	contents
1	chloroplast suspension, DCPIP and distilled water
2	chloroplast suspension, DCPIP and weed killer X
3	chloroplast suspension, DCPIP and weed killer Y
4	chloroplast suspension, DCPIP and weed killer Z

- The foil was removed and the tubes were illuminated as in the original investigation shown in Fig. 1.3.
- After 10 minutes the student used a colorimeter to measure the absorption value of the contents of each tube.
- The investigation was repeated a number of times and means were calculated.
- *t*-tests were used to compare the results for the tubes.

The results of all the *t*-tests are shown in Table 1.4.

Table 1.4

	<i>p</i> < 0.05		
contents of tube	no weed killer added	weed killer X	weed killer Y
no weed killer added			
weed killer X	not significant		
weed killer Y	significant	significant	
weed killer Z	significant	not significant	not significant

(i) Suggest a null hypothesis for the *t*-test used for tubes 1 and 2.

.....
 [1]

(ii) The *t*-tests were used to compare the means.
 State **one** feature of data that allows use of the *t*-test.

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 [1]

- (iii) The student calculated that there were 22 degrees of freedom in each of these t -tests. An equal number of replicates for each tube was carried out.

State the number of replicates of **each** tube that were carried out.

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..... [1]

- (iv) The critical value for t at $p < 0.05$ in this investigation was 2.07.

State what the results in Table 1.4 tell you about the student's **calculated value** of t when comparing the effect between weed killers **X** and **Y**.

..... [1]

[Total: 22]

MAY/JUNE 2018 Variant 53

- 1 Sodium hydrogencarbonate indicator solution contains sodium hydrogencarbonate.

Some students found out on the internet that this indicator solution changes colour with pH. The students also discovered that this indicator is used to determine the concentration of carbon dioxide in a solution.

The students decided to use this indicator to measure the rate of photosynthesis in algal balls. Algal balls are unicellular algae that are immobilised in alginate.

The students assumed that the rate of carbon dioxide uptake was proportional to the rate of photosynthesis.

Fig. 1.1 shows the apparatus that the students used.

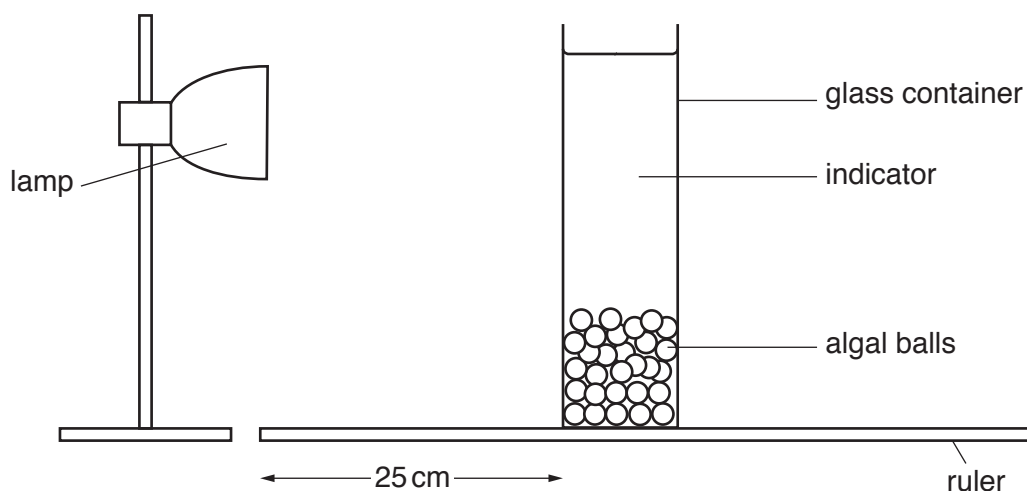


Fig. 1.1

A laboratory technician prepared a series of test-tubes containing hydrogencarbonate indicator solution from pH 7.6 to pH 9.2. The colour of the indicator solution in each test-tube is described in Table 1.1.

Table 1.1

← increasing CO ₂ in indicator solution				decreasing CO ₂ in indicator solution →				
pH 7.6	pH 7.7	pH 8.0	pH 8.2	pH 8.4	pH 8.6	pH 8.8	pH 9.0	pH 9.2
light yellow	dark yellow	light orange	dark orange	red	light magenta	dark magenta	light purple	dark purple

- (a) Suggest what was added to each of the test-tubes to maintain the pH.

..... [1]

- (b) Unicellular algae can be immobilised using a technique that is similar to that used to immobilise enzymes.

Outline the method that the students would have used to immobilise the algae.

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..... [3]

- (c) The students used the apparatus shown in Fig. 1.1 and the colours described in Table 1.1 to investigate the effect of light intensity on the rate of photosynthesis.

The students proposed the following hypothesis:

As light intensity increases the rate of photosynthesis increases.

- (i) Identify the independent variable **and** the dependent variable in this investigation.

independent variable

dependent variable

[2]

- (ii) Describe a method the students could use to collect the data needed to test their hypothesis.

Your method should be set out in a logical way and be detailed enough to let another person follow it.

You should **not** repeat any details from **(b)** about how to prepare immobilised algal balls.

..... [5]

- (iii) The students were concerned that the lamp may have increased the temperature of the solution in the container. Suggest how they could have attempted to control this variable.

..... [1]

- (d) The light intensity (I) can be calculated using the formula shown in Fig. 1.2.

$$I = \frac{1}{\text{distance}^2}$$

Fig. 1.2

Use the formula in Fig. 1.2 to calculate the light intensity for the experiment shown in Fig. 1.1.

$I = \dots\dots\dots$ [1]

The students decided that using a pH probe would give them more accurate data. They decided to measure the pH change for **one** value of light intensity.

Fig. 1.3 shows their results.

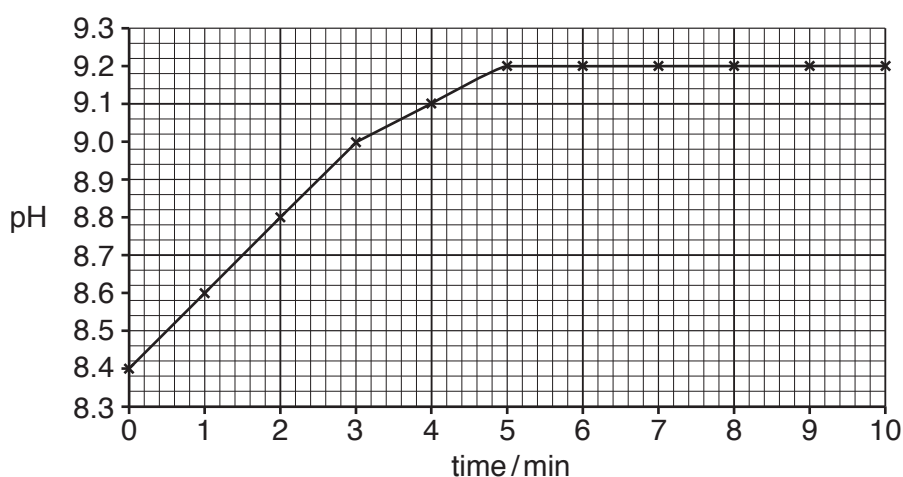


Fig. 1.3

- (e) (i) State why the use of a pH probe provides more accurate data.

$\dots\dots\dots$ [1]

- (ii) The data shown in Fig. 1.3 were for a high light intensity.

On Fig. 1.3, sketch the curve that you would expect for a low light intensity. [1]

- (iii) State why carbon dioxide is **not** a limiting factor in this investigation.

$\dots\dots\dots$
 $\dots\dots\dots$ [1]

- (f) Certain weed killers work by reducing the rate of photosynthesis.

The students modified their method to investigate the effect of three different weed killers on algae at the same light intensity.

The investigation was replicated a number of times and the pH was recorded after 30 minutes. The students calculated the mean pH for each treatment, as shown in Table 1.2.

The students carried out *t*-tests to compare the mean pH for each of the treatments that used weed killers with the treatment that used no weed killer (treatment 1). The students calculated the value of *t* for each of the tests.

Table 1.2 shows the results from their investigation.

Table 1.2

treatment	contents	mean pH after 30 minutes	<i>p</i> value
1	algal balls, indicator and distilled water	9.2	
2	algal balls, indicator and weed killer A	8.5	< 0.001
3	algal balls, indicator and weed killer B	9.0	> 0.05
4	algal balls, indicator and weed killer C	8.7	< 0.05

- (i) Suggest a null hypothesis for comparing the effect of treatment 2 with treatment 1.

.....
 [1]

- (ii) The *t*-tests were used to compare the means.

State **one** feature of data that allows use of the *t*-test.

.....
 [1]

- (iii) When calculating the effect of weed killer **A** on the rate of photosynthesis, 15 degrees of freedom was chosen. The students carried out 7 replicates of treatment 1.

State how many replicates were carried out for treatment 2.

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 [1]

- (iv) The students concluded that the weed killers had a significant effect on the rate of photosynthesis.

Explain to what extent the p values in Table 1.2 support their conclusion.

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..... [3]

[Total: 22]

OCT/NOV 2018 Variant 51

- 1 Transpiration in plants can be investigated using a potometer, which measures water uptake by plants. Fig. 1.1 shows a potometer that was used by a student.

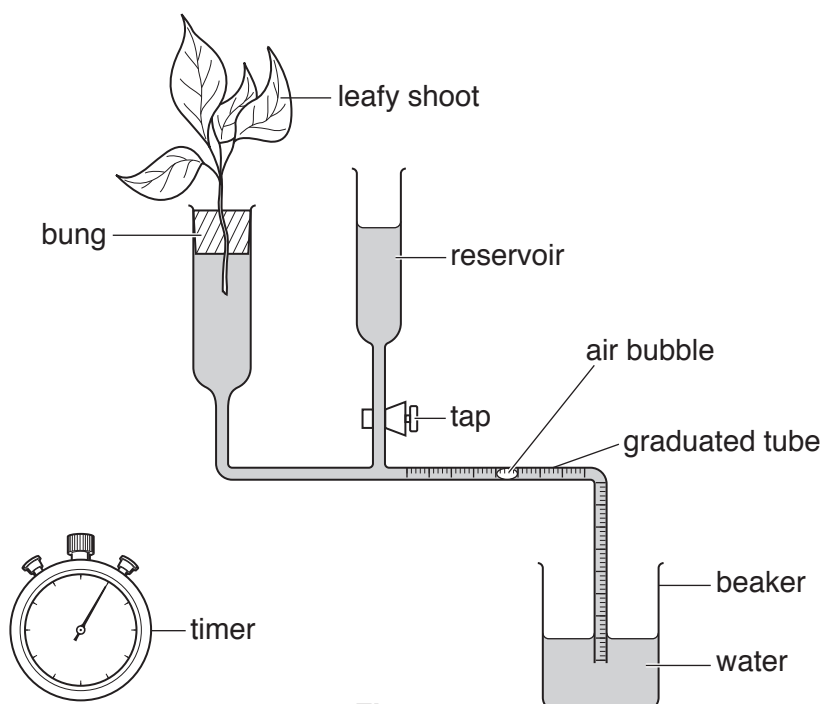


Fig. 1.1

As water is lost by the leaves through transpiration, the air bubble moves along the graduated tube.

The student used this apparatus to investigate the effect of light intensity on the rate of transpiration in plants.

- (a) (i)** State the independent variable **and** the dependent variable in this investigation.

independent

dependent

[2]

- (ii) List **three** variables that should be controlled in this investigation **and** describe how the student could standardise **two** of these variables.

.....[3]

[3]

.....[6

- (c) The student carried out further experiments, using the same apparatus, to investigate the effect of two different environmental carbon dioxide concentrations on the rate of transpiration. These experiments were carried out at a high light intensity and at a low light intensity.

The leafy shoots used in the experiments were taken from the same plant and each shoot had five leaves.

The student calculated the percentage reduction in the transpiration rate from 50 ppm to 730 ppm of carbon dioxide at low light intensities.

The results are shown in Table 1.1.

Table 1.1

concentration of carbon dioxide / ppm	light intensity	transpiration rate / $\text{g dm}^{-3} \text{ hr}^{-1}$	percentage reduction in transpiration rate from 50 ppm to 730 ppm of carbon dioxide
50	low	1.28	36.7
730	low	0.81	
50	high	3.03	
730	high	2.12	

ppm = parts per million

- (i) Complete Table 1.1 by calculating the percentage reduction in transpiration rate from 50 ppm to 730 ppm of carbon dioxide at the **high light intensity**.

Show your working.

[2]

- (ii) The student concluded that, as carbon dioxide concentration increased, the transpiration rate in plants decreased at all light intensities.

Explain why this conclusion may **not** be valid.

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.....[2]

[Total: 15]

OCT/NOV 2018 Variant 52

- 1 Fig. 1.1 shows apparatus that can be used to measure the loss of water vapour from leaves.

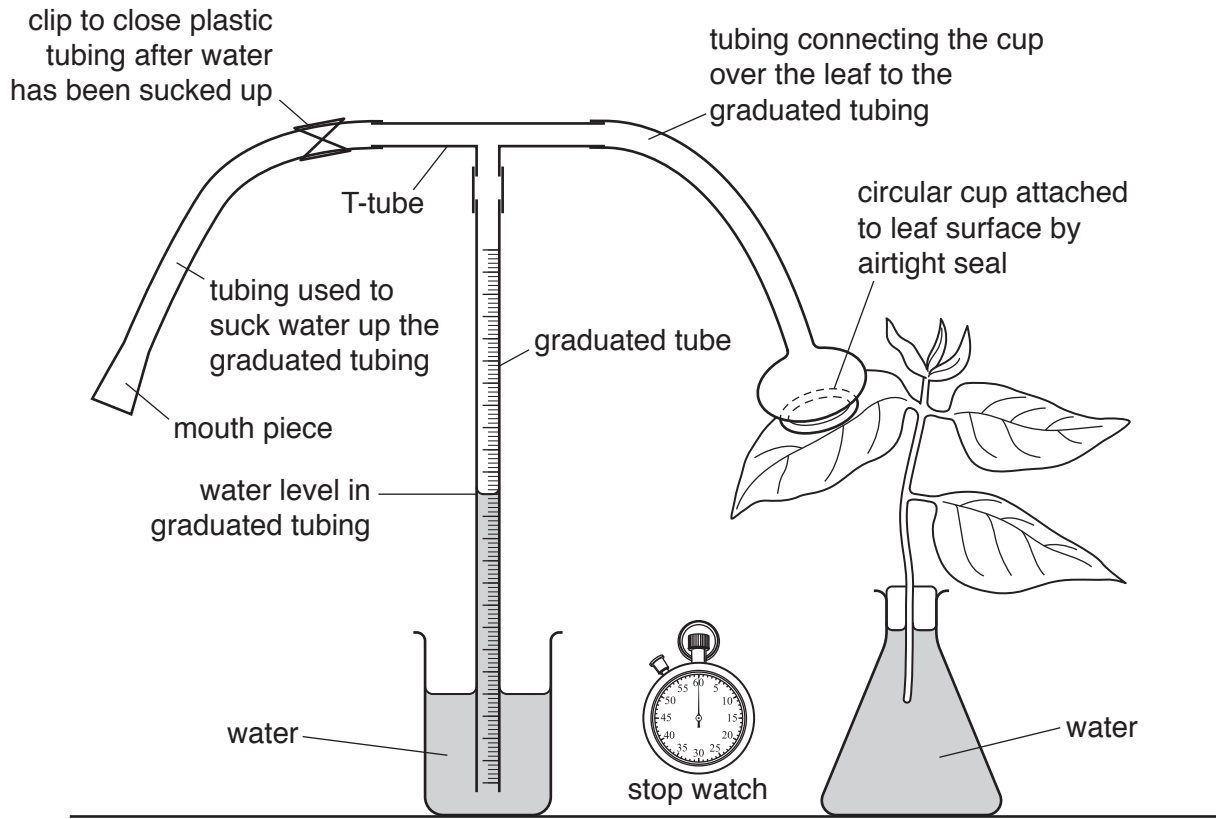


Fig. 1.1

The water vapour given out by the area of leaf under the cup increases the pressure inside the tubing, causing the water level in the graduated tube to go down.

Some students used the apparatus in Fig. 1.1 to test the hypothesis:

The loss of water vapour from the lower surface of the leaves of a plant is greater per unit time than the loss of water vapour from the upper surface of the leaves of the same plant.

- (a) (i) State the independent variable **and** the dependent variable in this investigation.

independent variable

.....

dependent variable

.....

[2]

- (ii) Describe a method by which the students could use the apparatus shown in Fig. 1.1 to measure loss of water vapour in order to test the hypothesis.

Your method should be set out in a logical order and be detailed enough to let another person follow it.

[6]

- (b) The hypothesis that the students tested was:

The loss of water vapour from the lower surface of the leaves of a plant is greater per unit time than the loss of water vapour from the upper surface of the leaves of the same plant.

The students decided that, to make a valid comparison, they needed to work out the water loss per unit time per unit area of leaf.

- (i) Describe how the students obtained the measurement needed to work out the results as **per unit area** of leaf.

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.....[2]

- (ii) Describe how the students could use this measurement and their results for the loss of water vapour to find out if their results support the hypothesis.

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.....[3]

- (iii) Sketch a bar chart on Fig. 1.2 to show the results if the hypothesis was supported. You should include the axis labels and the units. [3]



Fig. 1.2

- (c) The apparatus shown in Fig. 1.1 was used in another series of experiments to measure water vapour loss from the same leaf in different experimental conditions for the same period of time.

Table 1.1 shows the results.

Table 1.1

experimental condition	distance moved by water column /cm per unit time				
	trial 1	trial 2	trial 3	trial 4	trial 5
high light intensity	7.3	7.5	7.8	6.2	7.0
no light	0.0	0.0	1.5	0.2	0.0
high temperature	4.4	2.8	3.2	4.8	3.1
strong air current	1.5	2.4	1.1	0.9	1.0

- (i) **On Table 1.1**, draw circles around **two** of the values that may be anomalous. [2]
- (ii) The aperture of stomata affects the loss of water vapour.

State **one** conclusion that can be made about the effect of experimental conditions on the aperture of stomata in this plant.

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.....[1]

[Total: 19]

MARCH 2020

- 1 Seaweeds are photosynthetic multicellular organisms found on the coast of many parts of the world. There are green, brown and red seaweeds.

During a field study, some students observed that the differently coloured seaweeds grew at different distances from the highest part of the shore reached by the sea (the high tide line).

Fig. 1.1 shows the distribution of these differently coloured seaweeds.

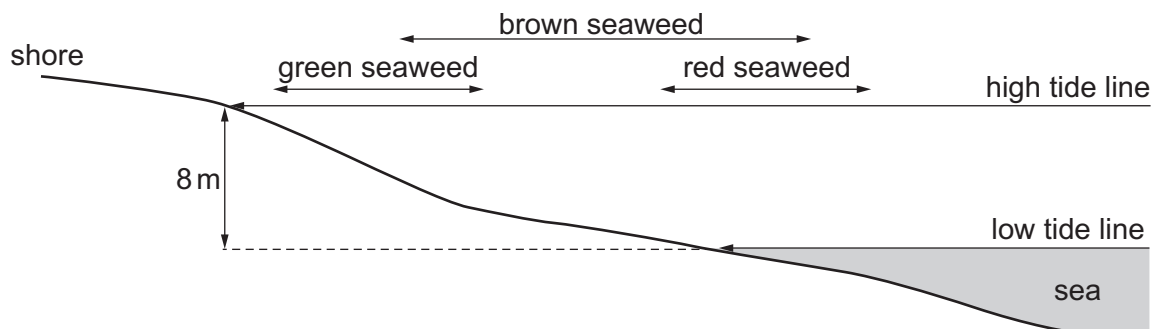


Fig. 1.1

The students were asked to compare the action spectra of the differently coloured seaweeds.

The students decided to:

- make a suspension of chloroplasts from each of the differently coloured seaweeds
- for each suspension of chloroplasts, find the time for methylene blue to change colour at different wavelengths of light.

Methylene blue is a redox indicator that changes colour from blue to colourless as a result of the reactions of the light dependent stage of photosynthesis.

- (a) State the independent variable and the dependent variable in the experiment to find the action spectrum of green seaweed.

independent variable

.....

dependent variable

.....

[2]

- (b) From the internet, the students found that:

- a chloroplast suspension can be obtained from a suspension of crushed seaweed tissue by filtering out and discarding the large fragments
- chloroplasts in suspension are easily destroyed by enzyme activity
- chloroplasts in suspension can burst by absorbing too much water by osmosis
- light of different wavelengths can be obtained from a light source using light filters of different colours, e.g. a red filter only transmits (allows through) red light from a light source.

(i) The students were provided with the materials listed.

- samples of green seaweed, brown seaweed and red seaweed in sea water
- bench lamp
- light filters of different colours that transmit light at known wavelengths
- ice cold phosphate buffer solution at pH 7
- 5 cm³ dilute methylene blue solution with a dropping pipette
- squares of small mesh cloth for filtering suspensions
- crushed ice in a shallow plastic bowl
- balance
- scissors
- mortar and pestle
- blender
- 1 cm³, 5 cm³ and 10 cm³ syringes
- 50 cm³ measuring cylinder
- metal foil
- 100 cm³ beakers
- test-tubes
- test-tube rack
- stop-clock or timer
- white tile or white card

Describe how the students could use this apparatus to:

- prepare a suspension of chloroplasts from each of the differently coloured seaweeds
- find the time for methylene blue to change colour at different wavelengths of light for each of the chloroplast suspensions.

Your method should be set out in a logical order and be detailed enough to let another person follow it.

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- (ii) Describe how the students could use their results to find the action spectrum for each of the differently coloured seaweeds.

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..... [2]

- (c) In another experiment, the students used thin layer chromatography to separate the chloroplast pigments from each of the differently coloured seaweeds.

Fig. 1.2 shows the chromatogram obtained and the colours of the pigments.

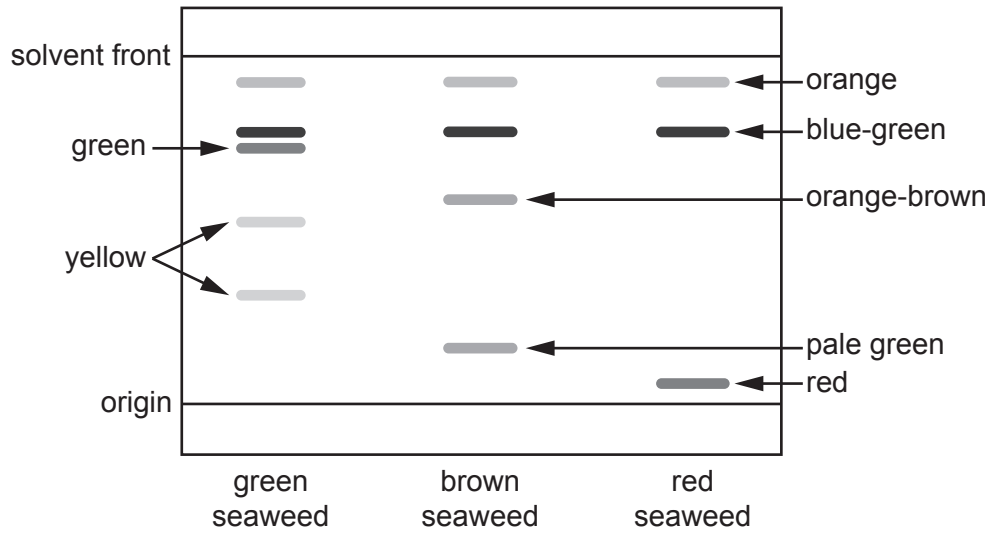


Fig. 1.2

- (i) Compare the chloroplast pigments present in the three differently coloured seaweeds, as shown in Fig. 1.2.

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..... [2]

- (ii) The students suggested that brown seaweed and red seaweed can photosynthesise in deeper water than green seaweed, due to differences in their pigments. The students based this suggestion on their observations shown in Fig. 1.1 and their results shown in Fig. 1.2.

The students found the wavelengths of light absorbed by each of the different chloroplast pigments that are shown in Fig. 1.2.

Table 1.1 shows the range of wavelengths at which light is absorbed by each of these pigments.

Table 1.1

pigment colour	wavelengths of light absorbed/ nm
orange	425–475
blue-green	412–435 and 640–685
green	420–476 and 635–652
pale green	447–452
yellow	400–530
orange-brown	390–580
red	490–500 and 545–565

The depth that light reaches into water is dependent on wavelength. The shorter the wavelength, the further light can travel into water.

Discuss whether or not the data in Table 1.1 support the suggestion that brown seaweed and red seaweed can photosynthesise in deeper water than green seaweed, due to differences in their pigments.

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..... [2]

[Total: 18]

MARCH 2022

- 1 Some students wanted to investigate the effect of light intensity on the rate of photosynthesis in the Brazilian waterweed, *Egeria densa*. This plant is found in freshwater ponds.

The students used the apparatus shown in Fig. 1.1 in their investigation. A stand and clamp were used to hold the apparatus in a vertical position.

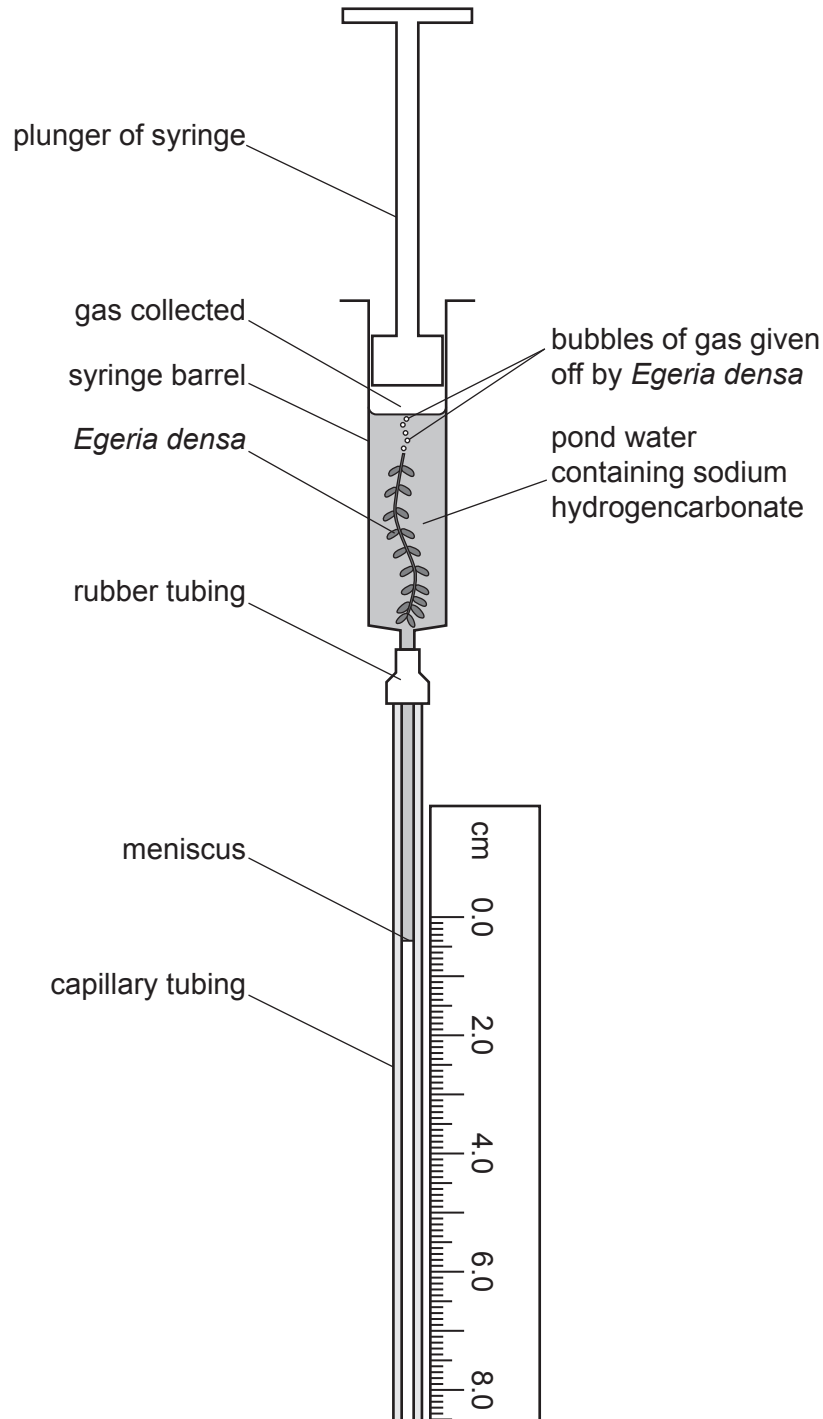


Fig. 1.1

The students carried out these steps to set up the apparatus shown in Fig. 1.1.

- Some sodium hydrogencarbonate was added to a sample of pond water as a source of carbon dioxide.
- The syringe barrel was filled with the pond water containing sodium hydrogencarbonate.
- A fresh piece of *E. densa* was cut under water.
- The cut stem was quickly placed in the pond water in the syringe barrel.
- The plunger was replaced, as shown in Fig. 1.1, and adjusted until the meniscus in the capillary tubing was near the top of the scale.
- A bench lamp was used as a light source.

The students noticed that bubbles of gas were given off from the *E. densa*. As the gas collected in the syringe barrel, the meniscus moved down the capillary tube. The plunger of the syringe did not move.

The students used the apparatus to investigate the effect of different light intensities on the rate of photosynthesis in *E. densa*.

(a) Suggest a suitable control for this investigation.

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..... [1]

- (b) (i)** Describe a method, using the apparatus shown in Fig. 1.1, that the students could use to investigate the effect of light intensity on the rate of photosynthesis of *E. densa*.

Your method should be set out in a logical order and be detailed enough to allow another person to follow it.

The steps carried out to set up the apparatus shown in Fig. 1.1 should **not** be included.

..... [7]

- (ii) Complete the sketch graph to predict the results that you would expect from the method you have given in (b)(i).

Include axis labels with units in your answer.



[3]

- (c) The students decided to use paper chromatography to separate the photosynthetic pigments found in *E. densa* leaves.
- *E. densa* leaves were ground up in a small volume of solvent to make a concentrated solution of pigments.
 - The different pigments in the solution were separated using paper chromatography.
 - The distance moved by the solvent was measured on the completed chromatogram.
 - The distances moved by the pigments were also measured.
 - The R_f values were calculated for these pigments.

Table 1.1 shows the results.

Table 1.1

pigment number	colour of pigment	distance moved by pigment/mm	distance moved by solvent/mm	R _f value
1	orange	105	107	0.98
2	yellow	94	107	
3	blue-green	62	107	0.58
4	green	45	107	0.42

- (i) Complete Table 1.1 by calculating the R_f value for pigment 2.

Give your answer to two significant figures.

The formula for the calculation of R_f is:

$$R_f = \frac{\text{distance moved by pigment}}{\text{distance moved by solvent}}$$

[1]

- (ii) The students used a published source to find the R_f values for three of the pigments that they expected to be present.

- R_f of carotene = 0.95
- R_f of chlorophyll *a* = 0.60
- R_f of chlorophyll *b* = 0.50

The students correctly identified pigment 1 as carotene, pigment 3 as chlorophyll *a* and pigment 4 as chlorophyll *b*.

The calculated R_f values were not exactly the same as the R_f values in the published source.

Describe **one** difficulty with paper chromatography that could explain why the R_f values calculated by the students were **not** exactly the same as the published data.

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..... [1]

[Total: 13]

MAY/JUNE 2023 Variant 53

- 1 Hydrogencarbonate indicator is a water-soluble solution that can act as a source of carbon dioxide for aquatic photosynthetic organisms. The solution changes colour depending on the concentration of carbon dioxide in the solution. These colours are related to different pH values, as shown in Table 1.1.

Table 1.1

colour of hydrogencarbonate indicator solution	pH	concentration of carbon dioxide in the solution
yellow	7.6	 increasing carbon dioxide concentration
yellow-orange	7.8	
orange	8.0	
orange-red	8.2	
red	8.4	atmospheric concentration
red-magenta	8.6	 decreasing carbon dioxide concentration
magenta	8.8	
magenta-purple	9.0	
purple	9.2	

Chlorella vulgaris is a protist that is single-celled, aquatic and photosynthetic. It can be immobilised in alginate beads.

Alginate beads with immobilised *C. vulgaris* can be used to measure the rate of photosynthesis.

- (a) A student noticed that a colour change occurred, from red to magenta, when the alginate beads with immobilised *C. vulgaris* were left in a container of hydrogencarbonate indicator solution and exposed to light.

Explain why this colour change occurred.

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..... [2]

- (b) The student used the alginate beads with immobilised *C. vulgaris* in hydrogencarbonate indicator solution to investigate the rate of photosynthesis in different light intensities.

Fig. 1.1 shows some of the apparatus and reagents the student used.

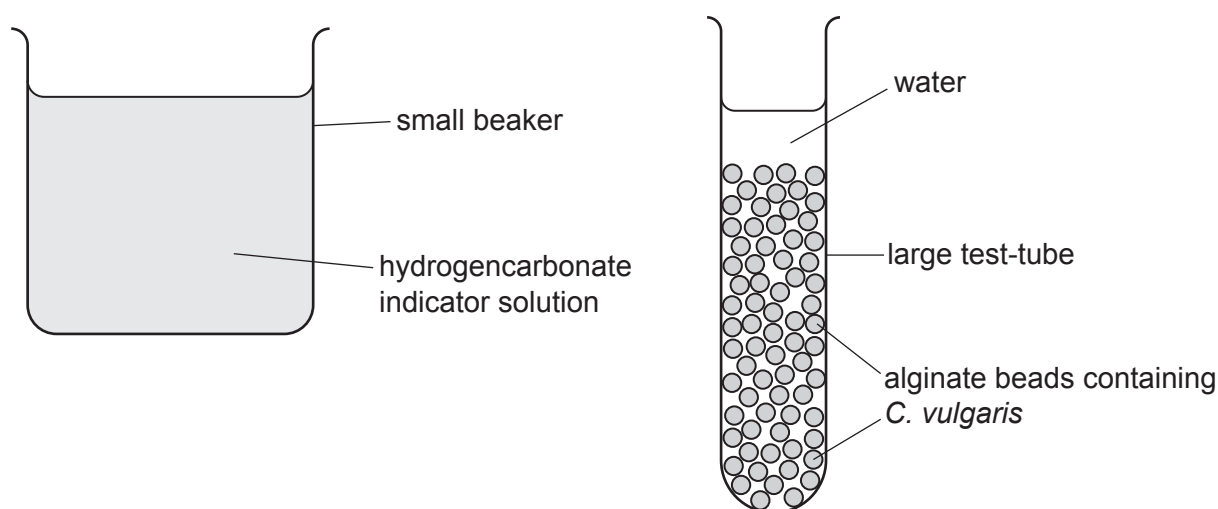


Fig. 1.1

- (i) Identify the **independent** variable in this investigation.

..... [1]

- (ii) The student was provided with a supply of alginate beads containing immobilised *C. vulgaris*.

Describe a method the student could use to collect data to determine the effect of light intensity on the rate of photosynthesis of *C. vulgaris* using hydrogencarbonate indicator and the experimental set-up in Fig. 1.1.

Your method should be set out in a logical order and be detailed enough to let another person follow.

[8]

- (c) The student set up a large test-tube containing alginate beads with immobilised *C. vulgaris* in hydrogencarbonate indicator solution at **pH 8.4** (red).

The student kept this set-up in the dark for 12 hours.

Predict and explain the results that will be observed after 12 hours in the dark.

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..... [2]

- (d) Some scientists wanted to culture cells of *C. vulgaris* on a large scale for use as a biofuel.

To determine the optimal growing conditions for *C. vulgaris*, the scientists needed to determine the number of cells per cm^3 of suspension to monitor the population growth.

They tried two methods to determine the number of cells per cm^3 of suspension.

The first method used a Secchi stick, as shown in Fig. 1.2.

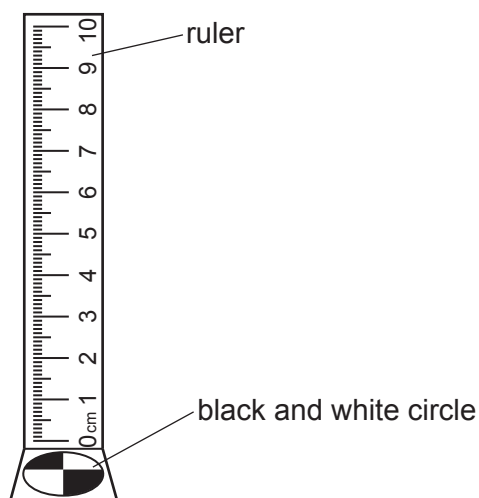


Fig. 1.2

The Secchi stick is lowered into the suspension of cells until the black and white circle is not able to be seen from above.

The depth in cm is recorded from the ruler, as shown in Fig 1.3.

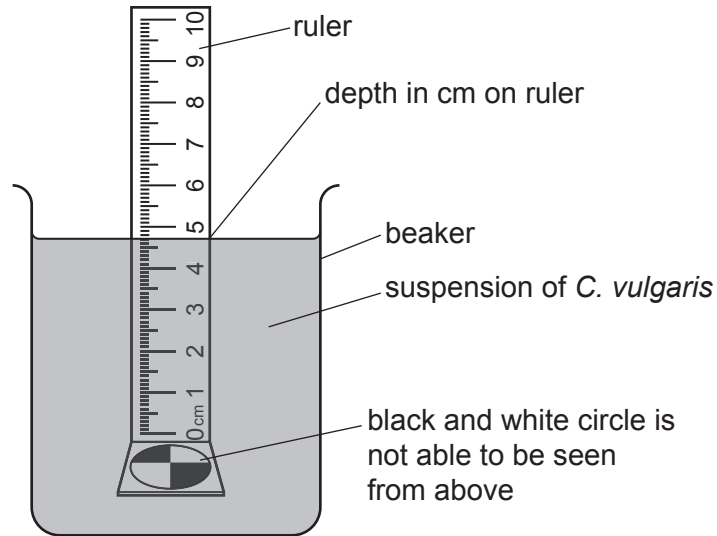


Fig. 1.3

The $\log_{10}$ (lg) of the number of cells is determined from a graph of $\log_{10}$ of cells counted per cm^3 suspension against Secchi depth (cm), as shown in Fig 1.4.

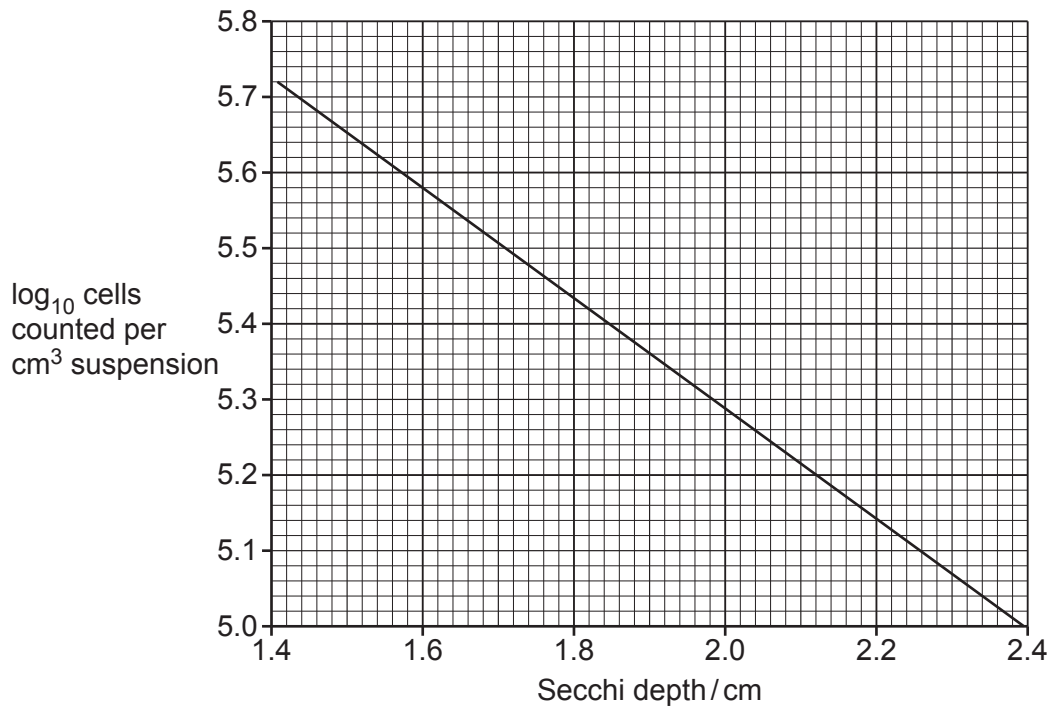


Fig. 1.4

- (i) When the scientists inserted the Secchi stick into a sample from their cell suspension, the circle (on the Secchi stick) was not able to be seen at a depth of **1.9 cm**.

Using the graph in Fig. 1.4, calculate the actual number of cells per cm^3 of suspension.

Show your working and give your answer to the nearest 1000 cells.

number of cells per cm^3 of suspension [2]

The second method used a counting chamber to determine the number of cells per cm^3 of suspension.

Fig. 1.5 shows a section of a counting chamber with cells present, as viewed using the high power of a light microscope.

The depth of the $1\text{ mm} \times 1\text{ mm}$ counting chamber is **0.1 mm**.

The scientists counted the number of cells in several sections of a counting chamber.

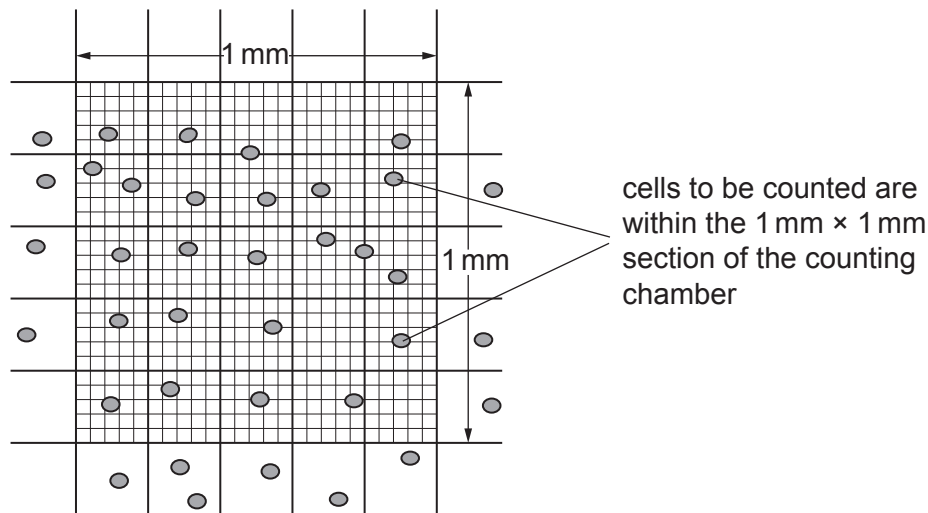


Fig. 1.5

- (ii) Count the number of cells in the $1\text{ mm} \times 1\text{ mm}$ section of the counting chamber shown in Fig. 1.5.

Use your answer to calculate the number of cells per cm^3 of the suspension.

Show all your working.

number of cells per cm^3 of suspension [3]

- (iii) The scientists decided that using the Secchi stick was a less accurate method for determining the number of cells per cm^3 of suspension.

Give **two** reasons why using the Secchi stick is less accurate than using a counting chamber.

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..... [2]

[Total: 20]

OCT/NOV 2023 Variant 52

- 2 Absciscic acid (ABA) is a plant hormone that influences the growth and development of plants.

Salicylic acid (SA) is a plant hormone that interacts with other plant hormones, such as ABA, to influence growth and development in plants.

Scientists investigated the effects of ABA and SA on shoot growth in seedlings of rice, *Oryza sativa*.

The scientists germinated some rice grains and divided the young seedlings into four batches, **A** to **D**, each containing 9 seedlings of the same length. The seedlings were put into trays containing a seedling growth medium. The shoots in each batch of seedlings were sprayed once with a different solution:

batch **A** – water

batch **B** – $2\mu\text{mol dm}^{-3}$ ABA

batch **C** – $2\mu\text{mol dm}^{-3}$ ABA + 1.0mmol dm^{-3} SA

batch **D** – 1.0mmol dm^{-3} SA

The seedlings were then put into a growth chamber with constant conditions of light, temperature and humidity. The length of the shoot on each seedling was measured one day after spraying and five days after spraying.

Fig. 2.1 shows two seedlings taken at random from each batch five days after being sprayed.

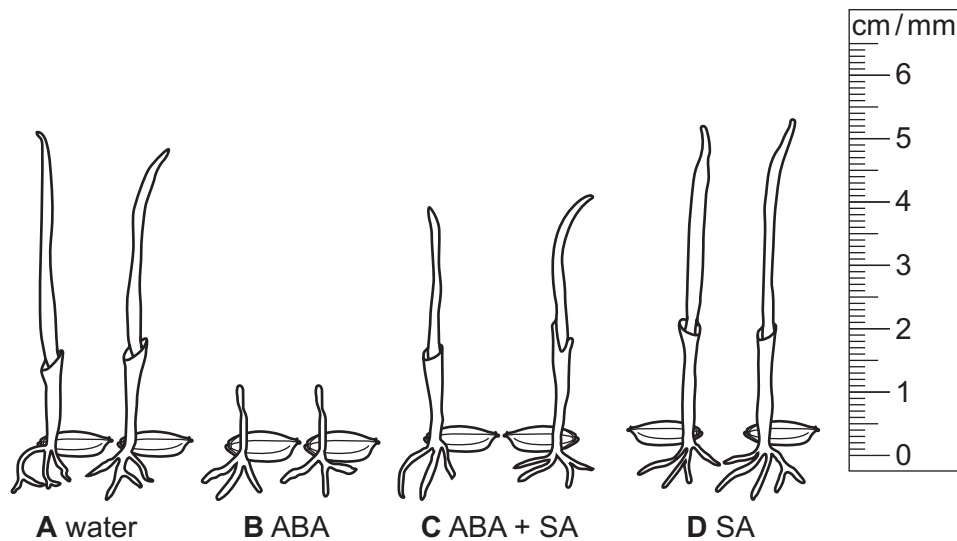


Fig. 2.1

The mean results of the investigation are shown in Fig. 2.2.

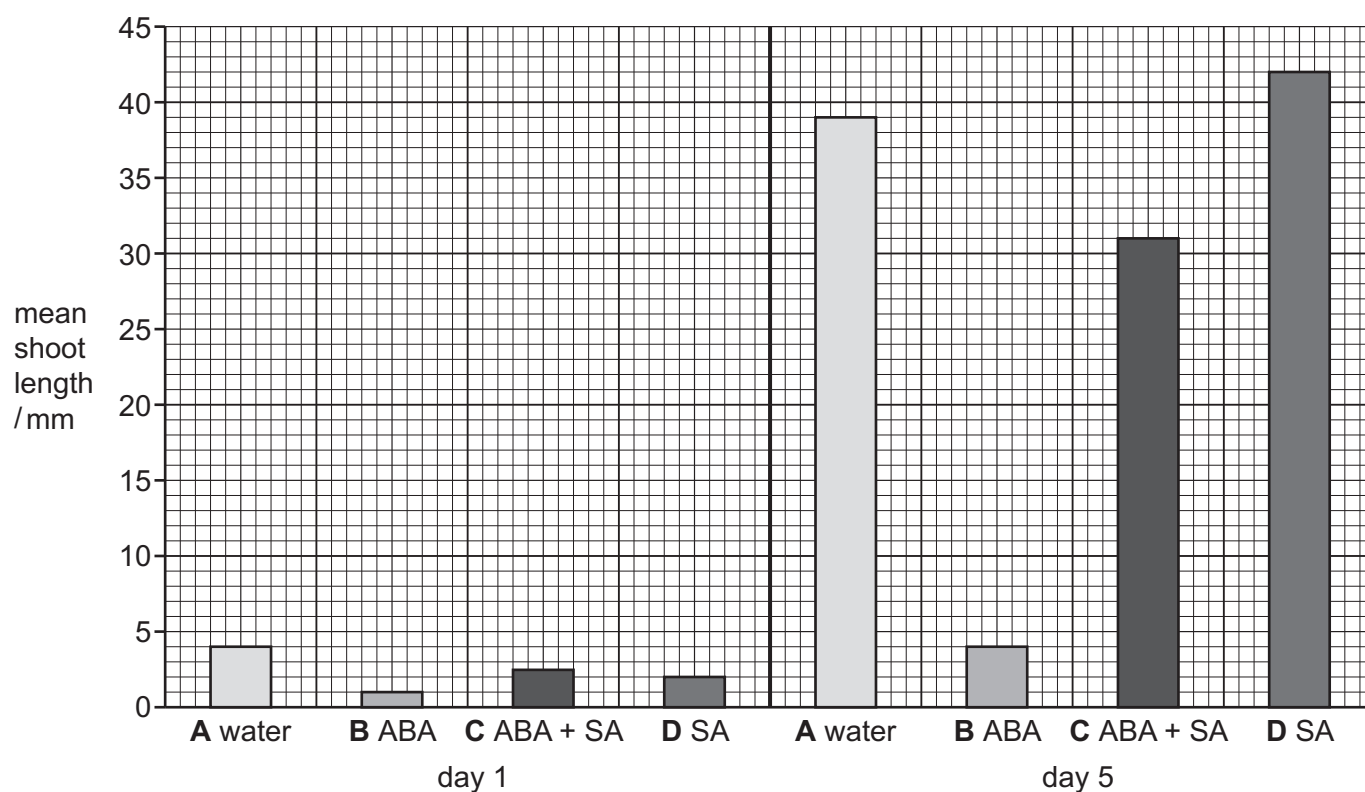


Fig. 2.2

(a) Seedlings do not always grow straight.

Suggest how the measurements of shoot length of the rice seedlings can be made as accurately as possible.

.....

 [1]

- (b) There were nine seedlings in each batch.

The standard deviation for the length of seedlings in batch **D** (sprayed with SA only) at day 5 is 5 mm.

The formula for calculating standard error (SE) is:

$$SE = \frac{s}{\sqrt{n}} \quad \begin{array}{l} s = \text{sample standard deviation} \\ n = \text{sample size (number of observations)} \end{array}$$

The formula for calculating the 95% confidence interval (95% CI) is:

$$95\% \text{ CI} = \bar{x} \pm (2 \times SE) \quad \bar{x} = \text{mean}$$

- (i) Calculate the 95% CI for batch **D** (treated with SA only) at day 5.

95% CI = mm [1]

- (ii) The values for 95% CI were used to add error bars for batches **C** and **D** at day 5. These error bars did not overlap. State what can be concluded from this.

.....

 [1]

- (c) Use the information in Fig. 2.2 to suggest **and** explain the effects of ABA and SA on the growth of the rice seedlings over five days.

.....

 [3]

- (d) The scientists delivered the plant hormones to the rice seedlings by spraying the shoots.

A student suggested that the rice seedlings could take up ABA and SA in the roots and transport the hormones to tissues in the shoot to give similar results to those in Fig. 2.2.

Outline a method to test this suggestion.

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..... [3]

OCT/NOV 2024 Variant 51

- 1 Algae are a diverse group of photosynthetic eukaryotes in the kingdom Protocista.

Rhodomonas salina and *Skeletonema costatum* are two species of alga that live in seawater.

Fig. 1.1 shows a scanning electron micrograph of *R. salina*, which is a unicellular organism. *R. salina* is red in colour.



Fig. 1.1

Fig. 1.2 shows a scanning electron micrograph of *S. costatum*, which is also a unicellular organism. The individual cells can group together in a chain. *S. costatum* is yellow-brown in colour.

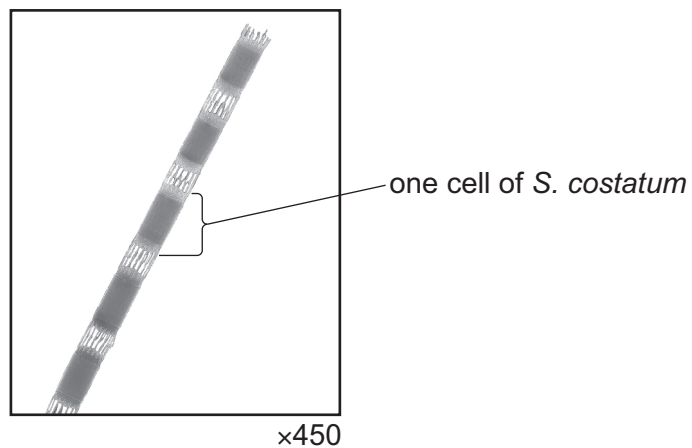


Fig. 1.2

- (a) A student prepared extracts of the photosynthetic pigments from *R. salina* and *S. costatum*. The student carried out chromatography to identify and compare the pigments in the two species.

The chromatograms are shown in Fig. 1.3.

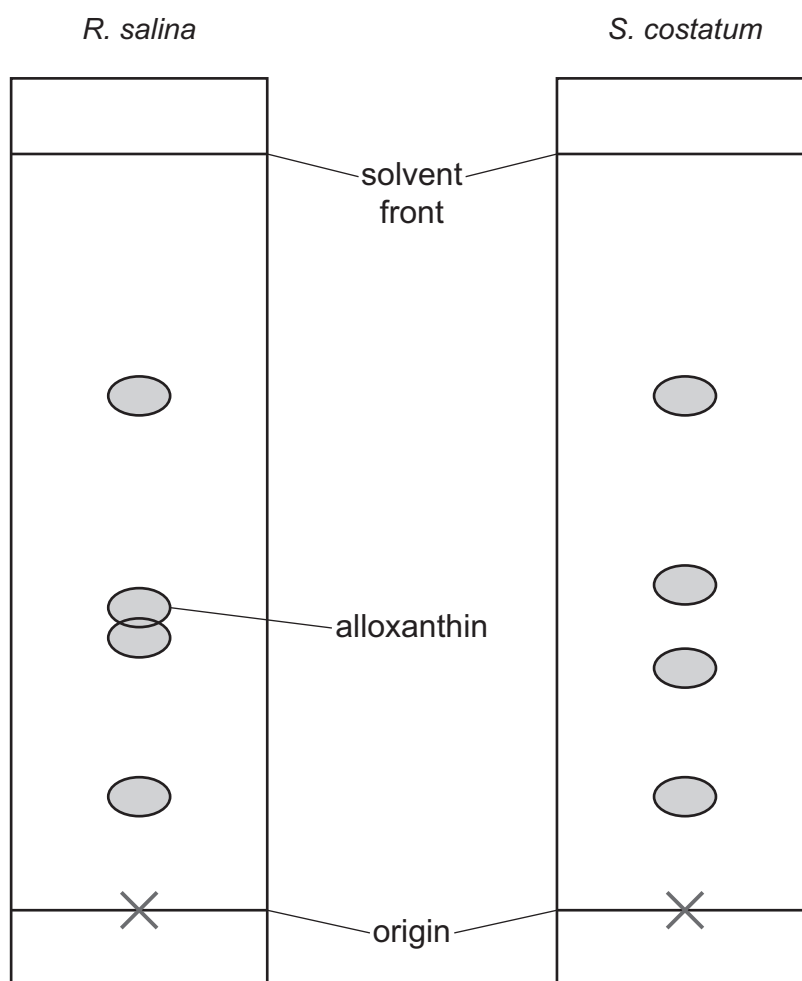


Fig. 1.3

- (i) Use Fig. 1.3 to calculate the R_f value of alloxanthin from *R. salina*.

R_f of alloxanthin = [1]

(ii) Table 1.1 shows the R_f values of some photosynthetic pigments.

Table 1.1

photosynthetic pigment	R_f value
β -carotene	0.94
chlorophyll a	0.68
chlorophyll b	0.54
chlorophyll c	0.15
diadinoxanthin	0.32
fucoxanthin	0.43
phycocyanin	0.35

R. salina lacks two photosynthetic pigments that are present in *S. costatum*.

Use Fig. 1.3 and Table 1.1 to identify the **two** photosynthetic pigments that are present in **only** *S. costatum*.

.....

..... [2]

- (b) The extract of the photosynthetic pigments from each of the two species was used to obtain absorption spectra as shown in Fig. 1.4.

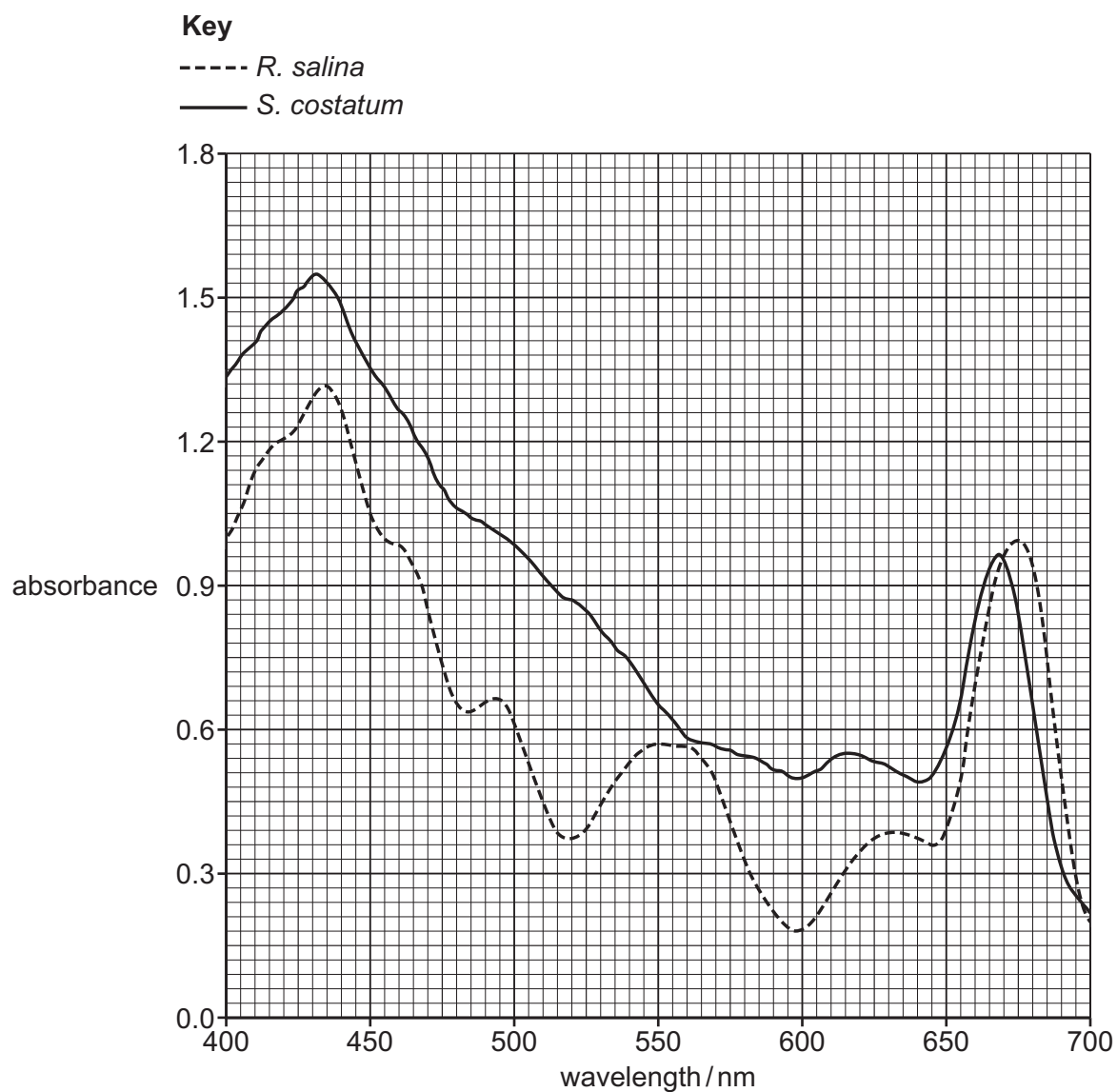


Fig. 1.4

The student planned to investigate the effect of light wavelength on the rate of photosynthesis in *R. salina* and *S. costatum*.

The student planned to determine the rate of photosynthesis in the two species when they were exposed to three different colours of light:

- blue light, peak wavelength of 455 nm
- green light, peak wavelength of 550 nm
- red light, peak wavelength of 670 nm.

Use Fig. 1.4 to compare the expected rates of photosynthesis for the two species in blue, green and red light.

blue light

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.....

green light

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.....

red light

.....

.....

[3]

- (c) In the investigation, the student used three different filters, blue, green and red, to expose the two species to the three different colours of light.

The student immobilised the algae in sodium alginate to form two sets of algal beads, one set for *R. salina* and one set for *S. costatum*.

The algal beads were the same size. Photosynthesis of the algae is **not** affected when they are immobilised in the beads.

The student placed the algal beads in small bottles for the experiment as shown in Fig. 1.5.

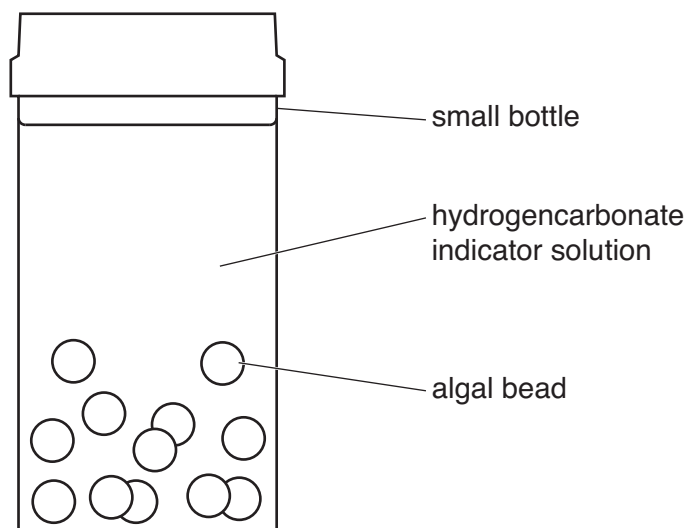


Fig. 1.5

The student used hydrogencarbonate indicator solution to estimate the rate of photosynthesis when the algal beads were exposed to each colour of light. The indicator solution changes colour with pH as shown in Table 1.2.

Table 1.2

colour of indicator solution	pH	CO ₂ concentration	rate of photosynthesis
yellow	7.6	↑ increasing concentration	↑ increasing rate ↓
yellow-orange	7.8		
orange	8.0		
orange-red	8.2		
red	8.4	atmospheric concentration (0.04%)	
red-magenta	8.6	↓ decreasing concentration	
magenta	8.8		
magenta-purple	9.0		
purple	9.2		

The student used pH change as an indirect measure of the rate of photosynthesis. A greater decrease in CO₂ concentration indicates a higher rate of photosynthesis.

For each bottle tested, the student:

- added algal beads to a small bottle containing indicator solution
- removed a sample of the indicator solution from the small bottle after some time
- used a colorimeter to measure the absorbance of the sample of the indicator solution.

The student used a calibration curve to estimate the pH of the samples of the indicator solution.

- (i) Suggest **one** reason why using algal beads, instead of placing the algal cells directly into the indicator solution in the bottles, improves the validity of the investigation.

.....

 [1]

- (ii) Identify the **two independent** variables and the **dependent** variable in this investigation.

independent variable 1

independent variable 2

dependent variable

[3]

- (iii) In addition to the colour filters, algal beads, small bottles, indicator solution and a colorimeter, the student had access to standard laboratory equipment.

The student carried out the investigation in a temperature-controlled room.

Describe a method the student could use to collect sufficient data so that the rates of photosynthesis of both species of alga in the three colours of light can be compared.

The description of your method should be set out in a logical way and be detailed enough for another person to follow.

You should **not** include a risk assessment or details of how to prepare the algal beads.

[8]

- (iv) Identify a hazard in this investigation **and** state a risk associated with the hazard **and** state one precaution that the student should take.

.....

 [1]

- (d) For each colour of light, the student carried out a statistical test to compare the pH of the samples taken from the small bottles that contained *R. salina* and *S. costatum*.

The student decided that a *t*-test was the most appropriate test to use for these data.

- (i) Suggest **one** reason why a *t*-test was the most appropriate test to use for these data.

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 [1]

- (ii) State a null hypothesis for this test.

.....

 [1]

[Total: 21]

OCT/NOV 2024 Variant 52

- 1 In the light-dependent stage of photosynthesis, electrons and hydrogen ions are accepted by the coenzyme NADP, which becomes reduced.

DCPIP is a dye that can act as an electron and hydrogen ion acceptor. The dye is blue when oxidised and colourless when reduced. In laboratory experiments, DCPIP can be used to follow the progress of the light-dependent stage because it can replace NADP as the acceptor molecule for electrons and hydrogen ions, as shown in Fig. 1.1.

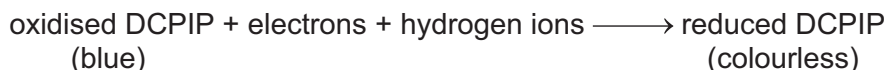


Fig. 1.1

The effects of various factors on the light-dependent stage of photosynthesis can be investigated by using suspensions of isolated chloroplasts (chloroplast suspensions) and DCPIP.

A student used DCPIP to investigate the effect of temperature on the rate of the light-dependent stage of photosynthesis in spinach, *Spinacia oleracea*.

The student prepared a leaf extract to make a stock chloroplast suspension and then carried out a preliminary experiment to determine a suitable concentration of chloroplast suspension to use in the investigation.

To carry out the preliminary experiment, the student followed a set of instructions, steps 1 to 11.

- 1 Cut spinach leaves into small pieces and place these pieces in a blender containing ice-cold 10% sucrose solution buffered at pH 7.0.
- 2 Turn on the blender for 15 seconds and then filter the extract to remove all the small pieces of leaf.
- 3 Place the leaf extract in a centrifuge and spin at low speed.
- 4 Pour off the supernatant that contains the chloroplasts. Keep this **stock chloroplast suspension** ice cold and in the dark.
- 5 Prepare 5 different concentrations of the chloroplast suspension using 10% sucrose solution. The percentage concentrations are 10%, 20%, 30%, 40% and 50% of the stock chloroplast suspension.
- 6 Wrap 5 flat-bottomed tubes in black plastic film to prevent light entering.
- 7 Put 10 cm³ of each concentration of stock chloroplast suspension into a flat-bottomed tube, and add 1 cm³ of DCPIP solution to each tube. The chloroplast suspension is now blue-green in colour.

- 8 Place 1 of the tubes beneath a light source as shown in Fig. 1.2.

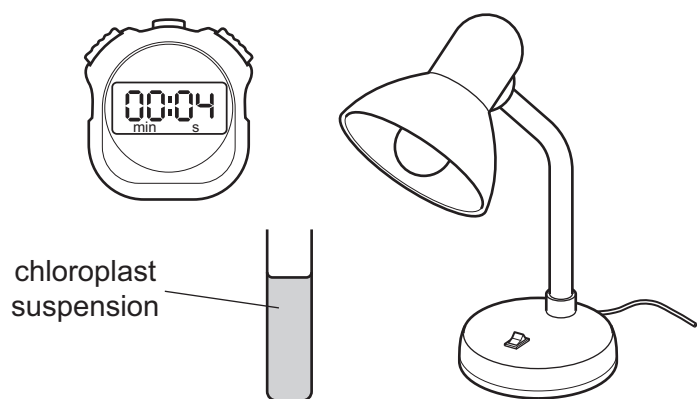


Fig. 1.2

- 9 Start a timer. Remove the black plastic film from the tube. Record the time taken for the DCPIP to decolourise so that the chloroplast suspension is green.
- 10 Calculate the rate of the light-dependent stage of photosynthesis by using the formula:

$$\text{rate} = \frac{1000}{t}$$

t = time taken in seconds for the chloroplast suspension to reach a green colour when all the DCPIP is decolourised.

- 11 Repeat step 8 to step 10 for the other tubes.
- (a) Suggest **two** suitable control experiments that the student should carry out as part of the preliminary experiment.

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2

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[2]

(b) The results of the preliminary experiment are shown in Table 1.1.

Table 1.1

percentage concentration of chloroplast suspension	time taken for DCPIP to decolourise /s	rate of light-dependent stage of photosynthesis /s ⁻¹
10	351	
20	59	
30	21	
40	10	
50	5	

- (i) Complete Table 1.1 by calculating the rate of the light-dependent stage of photosynthesis for each concentration of chloroplast suspension.

Give your answers to **one** decimal place.

[2]

- (ii) Plot a line graph of the data in Table 1.1 on the grid in Fig. 1.3 to show the effect of changing the concentration of the chloroplast suspension on the rate of the light-dependent stage of photosynthesis.

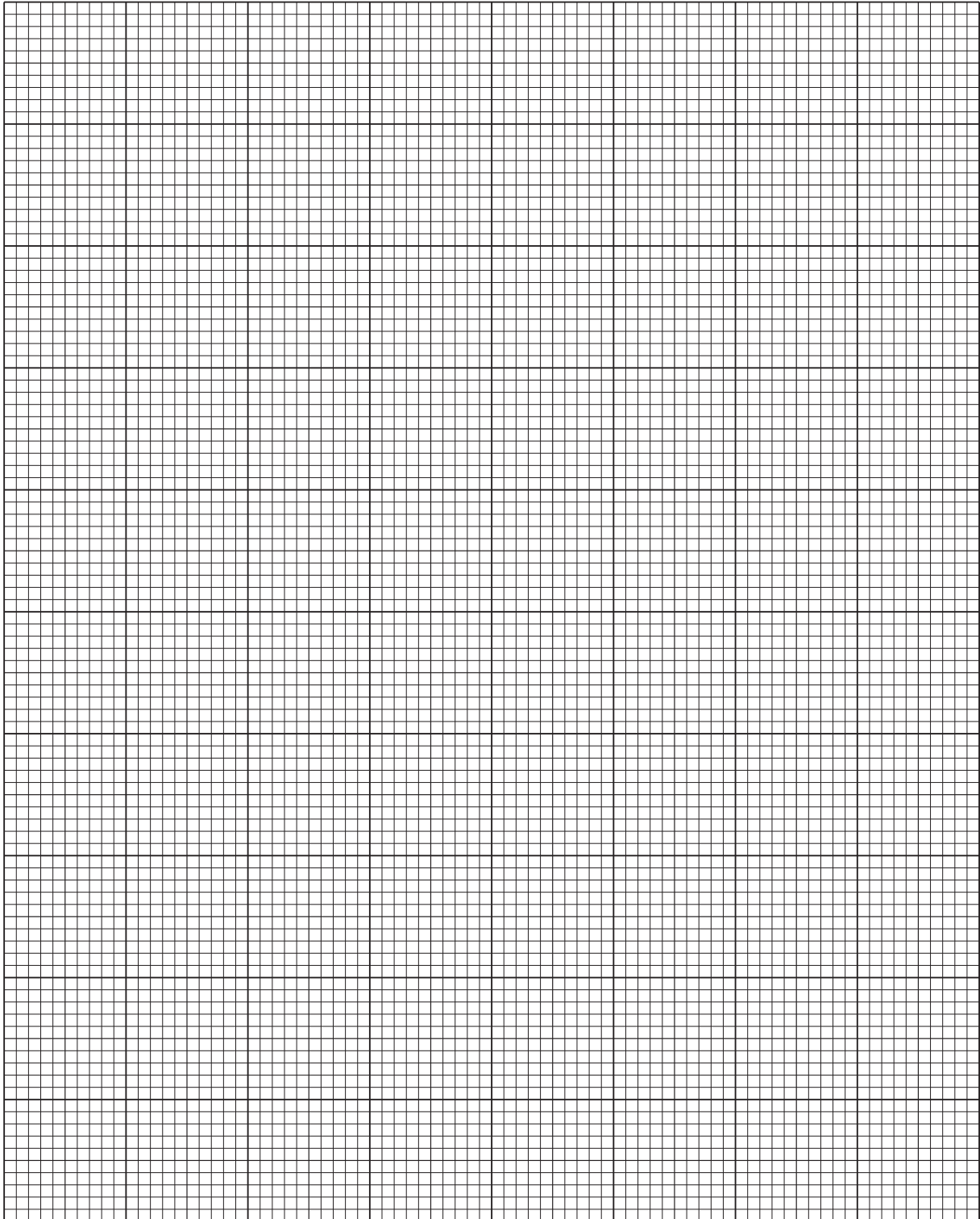


Fig. 1.3

[3]

- (c) The student initially trialled the experiment using ice-cold distilled water instead of ice-cold 10% sucrose to make the stock chloroplast suspension in step 1. The DCPIP did **not** decolourise.

Suggest why the procedure worked when 10% sucrose solution was used but did **not** work when distilled water was used in step 1.

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..... [2]

- (d) The preliminary experiment was carried out at 17 °C.

To investigate the effect of temperature on the rate of the light-dependent stage of photosynthesis, the student added some details to the instructions in steps 7, 8 and 9 to make sure that accurate results were recorded.

Describe an investigation that the student could follow to determine the effect of temperature on the rate of the light-dependent stage of photosynthesis.

- Use the results shown in Table 1.1 to decide on a suitable chloroplast suspension for the investigation.
- Include details of how you would take accurate results.
- Do **not** include a risk assessment.

Your method should be set out in a logical order and be detailed enough to allow another person to follow it.

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Classified by Mr.Adeel Ahmad